Krafft, Carl A. —

Spiral molecular structures
the enigma of life

SPIRAL MOLECULAR STRUCTURES THE BASIS OF LIFE

By

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Introduction.

There exists in nature a sharp line of demarcation between living things and inorganic things. The fundamental life processes, such as growth, variation, and reproduction are distinctly different from any of the known phenomena of physics or chemistry and are exhibited just as fully and completely by the simplest bacteria as by the highest plants and animals. Notwithstanding their diversity of shape and form, all living organisms must possess something in common which gives rise to that peculiar characteristic called "life".

If any particular physical structure constitutes the true cause of life processes, then such structural detail would have to occur in every living organism. But there are many bacteria which exhibit no physical heterogeneity whatever, except possibly an outer cell membrane, and it is inconceivable how any purely physical structure could of itself give rise to a phenomena like reproduction.

The Chemical Basis of Life.

That the fundamental life processes must be due, either wholly or partly, to specific chemical structures is generally conceded, but there is a prevailing opinion that the chemical structures which are necessary for this purpose must be extremely complex. There is, however, no very sound foundation for this opinion. The complex structures observed in the higher plants and animals are the result of evolution, and the fact that they are indispensible to the proper physiological functioning of certain higher organisms does not prove that they are the real cause of the fundamental life processes in the lower organisms. If extremely complex structures were necessary for life of any sort, then it would be highly improbable that life could ever have originated spontaneously.

It seems more reasonable to assume that life is due to some comparatively simple principle of chemistry which has not yet been discovered. To find the clue to this we must investigate the molecular structure of proteins, because proteins constitute nearly all the solid matter in the bodies of unicellular organisms after removal of the water.

All protein substances, upon hydrolytic decomposition, yield a mixture of amino acids having the following molecular structure:

$$NH_2\text{-}CRH\text{-}CO\text{-}OH,$$

where R may be any one of various complex groups. (E. Klarmann, Chemical Reviews, Vol. IV, p 51, 1927)

These amino acids will readily condense, with the elimination of water, to form either chain structures known as polypeptides, or ring structures known as diketopiperazines:

$$3\ NH_2.CRH.CO.OH =$$

$$NH_2.CRH.CO.NH.CRH.CO.NH.CRH.CO.CH + 2\ H_2O;$$

$$2\ NH_2.CRH.CO.OH =$$

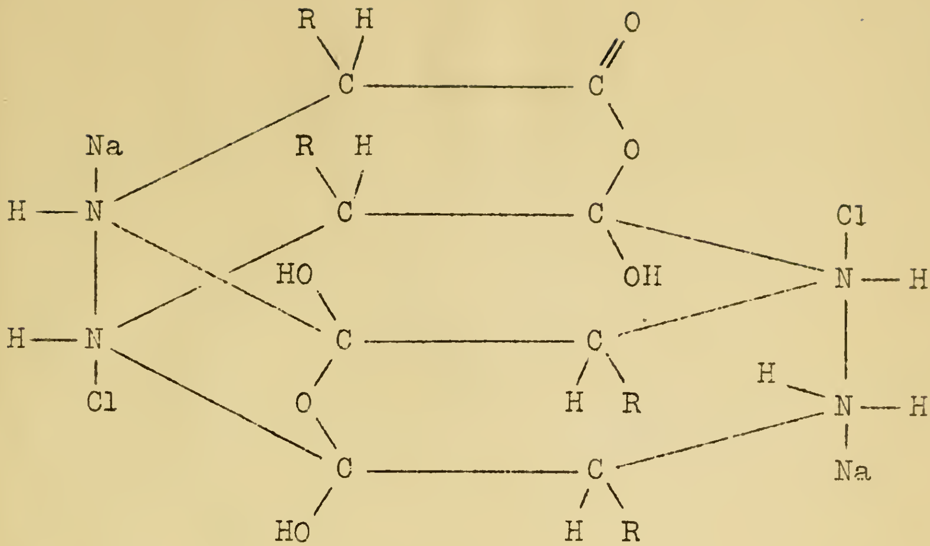
$$NH \begin{matrix} \diagup\ CRH - CO\ \diagdown \\ \diagdown\ CO - CRH\ \diagup \end{matrix} NH + 2\ H_2O.$$

(Emil Fischer, Untersuchungen über Aminosäuren, Polypeptide, und Proteïne, 1899 - 1906)

Since proteins constitute the principal structure-building food for animals, and upon digestion are changed to amino acids in which form they are assimilated by the tissues, it is generally thought that the phenomenon of growth involves condensation processes of a similar character.

Polypeptides will readily unite with additional amino acid molecules and thus undergo a process somewhat analogous to growth, but the different parts of the polypeptide molecule are not fixedly coordinated with one another in space so that it lacks that definite morphology which is characteristic of all living organisms. Diketopiperazines, on the other hand, do possess a somewhat more definite morphology, but will not condense with additional amino acid molecules. The essential characteristics of these two structures can, however, be combined.

If we assume that the valencies of the carbon atom are arranged like the corners of a regular tetrahedron, and that the three valencies of tri-valent nitrogen in amino compounds are about equally distributed around an equatorial circle, (which arrangement appears to be the only one which is consistent with all known chemical facts,) then the polypeptide chain, when coiled around on itself, will assume the form of a spiral or helix having substantially the same diameter as the diketopiperazine ring:



A polypeptide spiral in NaCl solution.

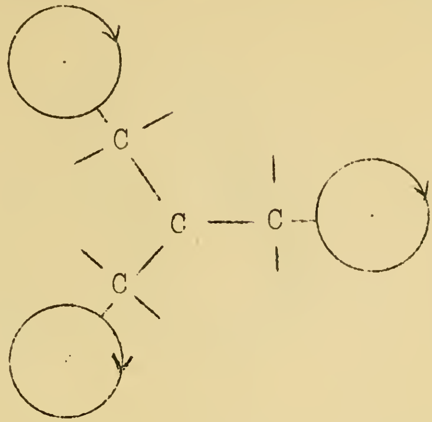
The nitrogen atoms will appear in two rows on opposite sides of the spiral, and the complex side chains represented by the R's in the above equations, as well as the carbonyl groups, will likewise arrange themselves along other diametrically opposite lines. Chemical union will probably take place between the successive carbonyl groups in the manner shown, and also between the successive nitrogen atoms, the fourth and fifth valencies of which are known to have a peculiar tendency to assume opposite charges. The nitrogen atoms at the ends of the spiral will probably unite with the ions of inorganic salts, the presence of which is necessary for the nourishment of all living organisms. It will be found, upon actually constructing this spiral of atomic models, that there is ample room for the complex side chains R if the fourth valency of the alpha carbon atom is occupied by hydrogen, but that the presence of more complex groups in this position would make the spiral structure impossible. We find, however, that the decomposition products of natural proteins always have a hydrogen atom in this position.

The resemblance in general shape and form of a polypeptide spiral to a bacillus will be apparent. It will be capable of growing endwise by condensation with additional amino acid molecules, and will possess definite morphology. It must remain permanently right-handed or left-handed, which would appear to account for the optical activity always exhibited by substances obtained from living organisms. It would also be capable of acquiring various arrays of side chains upon being nourished with different kinds of amino acids, and thus exhibit the characteristic of variability. It would not, however, be capable, upon division, of transmitting to its progeny any permanently inheritable variations, and could therefore not be regarded as a complete living organism.

The smallest living bacillus is about a thousand times larger than an individual polypeptide spiral, and very likely consists of large numbers of such spirals in parallel formation, either as a solid rod or as a hollow cylinder. The complex side chains represented by the R's in the above diagram evidently furnish the means for connecting together adjacent spirals. The arrangement and spacing of the different spirals will be subject to a certain amount of variation, depending on the nature of the molecular complexes which connect them, but whatever the arrangement is, it must necessarily be maintained throughout growth, and will, upon division, be transmitted to the progeny by a process of heredity.

It appears that there are only a limited number of ways in which adjacent spirals can be connected together. We may, for example, connect together two adjacent spirals edge to edge so as to form a flat sheet, but this arrangement cannot occur very extensively in nature because protoplasmic substances are usually three dimensional.

Next in order would be a connection between three adjacent spirals, which may be accomplished very readily as follows:



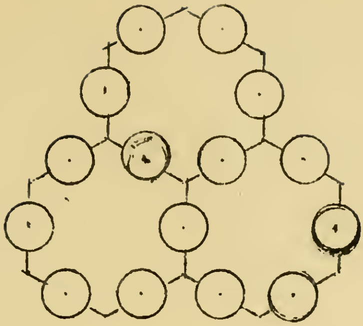
The existence of similar structures in nature is evidenced by the frequent occurrence, among protein disintegration products, of leucine,

$$\begin{matrix} CH_3 \searrow \\ CH_3 \nearrow \end{matrix} CH\text{-}CH_2\text{-}CHNH_2CO\text{-}OH,$$

which has a similar triple connection at the gamma carbon atom.

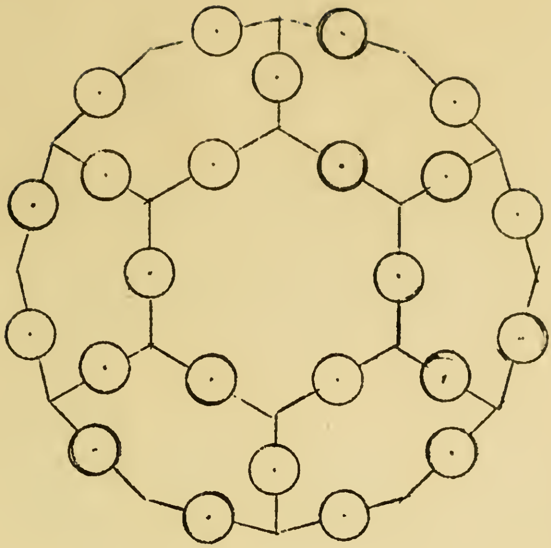
It appears to be at these triple junctions where some of the remarkable chemical changes occur which take place in living organisms. The three adjacent spirals hold their amino acid molecules in definitely coordinated positions, which should have a profound effect upon their chemical behavior.

The triple connection is probably the arrangement which occurs most frequently in nature, because a number of such groups will collectively form a cluster of hexagonal compartments, and we know that the hexagon is one of the few figures which will completely cover a certain area, as for instance the cross-sectional area of a bacillus.



The only other possibilities are rectangular and triangular campartments, but the existence of these appears highly improbable, except at the surfaces, because they would require the coupling together of four and six spirals respectively, which appears to be impossible of accomplishment with any known type of molecular structure.

A cluster of three polypeptide spirals with a complete triple junction at the center ought to possess all the fundamental characteristics of life, provided it can be equipped with a stable outer structure. A group of three hexagonal compartments as illustrated above could probably not exist in nature because each compartment would have three exposed outer corners which would render it very vulnerable. Regardless of how many additional hexagonal compartments we add to this structure, the maximum number of exposed corners can never be less than two. But at the surface of the organism there is no real necessity for confining ourselves to the use of hexagons. If, for example, we form the surface structure of pentagons instead of hexagons, the number of exposed corners on each compartment would be reduced to one, and our organism will appear in cross section somewhat as follows:



The outermost corners of the pentagons will probably not be formed by the gamma carbon atoms as in the case of hexagons, but there are substances such as cystine,

$$\begin{array}{l} S\text{-}CH_2.CHNH_2.COOH \\ | \\ S\text{-}CH_2.CHNH_2.COOH, \end{array}$$

among the decomposition products of proteins which suggest other types of structures for connecting together adjacent polypeptide spirals.

The presence of a peripheral region structurally different from the interior also seems to account for the tendency of unicellular organisms to divide. Except in rare cases of coincidence, different molecular structures would occupy different amounts of space, so that as the organism increases in length there will be a point reached when the expansive force of the more bulky structure will tear apart the less bulky structure, so as to cause the organism to divide into two halves. Most bacteria have rounded ends, which appears to indicate that the interior structure is more bulky than the peripheral structure, but there are a few species with concave ends in which the reverse condition appears to exist.

Conclusion.

Although the above hypothesis will not readily lend itself for verification by ordinary chemical analysis, yet its correctness is rendered highly probable by the fact that it appears to offer a satisfactory explanation of the following phenomena:

1. Growth;
2. Variability;
3. Spontaneous division;
4. Inheritance of structural variations;
5. The rod-like or thread-like form of many of the lower organisms;
6. The optical activity of substances obtained from living tissues;
7. The large percentage of water in living tissues;
8. The need for inorganic salts by all living organisms;
9. The remarkable chemical changes which occur during metabolism;
10. The necessity for amino acids with complex side chains for the nourishment of all animals;
11. The alpha position of the amino group in amino acids obtained from proteins;
12. The alpha hydrogen atom in such acids.